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ABSTRACT

Submaximal and maximal physiological parameters were measured on a progressive treadmill test in 11 Columbia University trackmen trained for various events. All runners were also tested in the 220, 440, 880, one-mile, and two-mile running events. Oxygen uptake was significantly related only to time in the one-mile run. Heart rates (HRs) at each submaximal load on the treadmill were significantly related to time in the one-mile run. For the two-mile run, HR at every submaximal load but one were significantly related to time. In these events, the runners with the lower treadmill submaximal HRs tended to do better. Conversely, in the 220-yard run higher submaximal HR seemed to be associated with lower times. However, the correlation coefficients were generally not quite significant. These data suggest that distance runners are characterized by high parasympathetic tone while sprinters are characterized by greater sympathetic tone. Furthermore, for this sample of subjects submaximal HR was better than maximal oxygen uptake as a predictor of distance running performance. (Author/PD)

Physiological Parameters Related to Running Performance in College Runners

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An understanding of the physiological capacities which underlie sports performance of various trypes can be helpful to coaches and physical educators who must make decisions about training methods and selection of athletes for various events and positions. One way of approaching this problem is to find the relationship between various events and the physiological parameters on which performance theoretically is based. For example, several studies have looked at the relationship between distance running performance and aerobic power (2, 3, 7, 9, 12). One problem with such studies is that they often have used groups which were rather heterogeneous in their general levels of activity and physical fitness, with the result that high correlations might be obtained between almost any event and aerobic power. For example, Falls (3) found that various items on the AAHPER fitness test were significantly correlated with aerobic power, including some (e.g. the shuttle run) which would not appear to be dependent on aerobic power. The present study utilized as subjects 11 members of a college track team, all of whom were relatively well-trained, but for different events.

Another problem with some previous studies is that only one event (e.g. the 2 mile run) was correlated with aerobic power and there was no way to tell whether aerobic power might have been just as closely correlated with shorter runs. The present study looked at the relations between aerobic power and events ranging from the 220 yard dash to the 2 mile run.

Since in distance events the runner actually works at a submaximal rather than a maximal level, we also included in the analysis submaximal heart rate (HR) and oxygen consumption (VO_2) measures to see whether these measures of circulatory and metabolic efficiency were related to performance.

Methods

The subjects were 11 males on the Columbia University track team. Two were sprinters, six middle distance runners and three long distance runners.

The laboratory testing included a predicted max VO_2 test on the cycle ergometer, using the Astrand-Ryhming procedure and a continuous and progressive treadmill test. The treadmill test used a speed of 3.5 mph and increments of 2.5 per cent every 2 minutes up to a self-imposed maximum. HR and VO_2 measures were obtained during the second minute at each workload, using a cardiotachometer and open circuit spirometry. Eight of 11 subjects achieved the plateau criterion of max VO_2 and all achieved maximum respiratory quotients very close to or above unity. However, three subjects mentioned that a limiting factor for them was leg pain at the higher treadmill grades, so a "true" max VO_2 might not have been attained.

The running events were conducted on an outdoor running track. All subjects ran the same event on the same day so that variations in environmental factors would influence them all similarly.

Results and Discussion

Table 1 shows some of the descriptive data for the subjects. The key point to note is that the mean max VO_2 of the subjects was not particularly high, which highlights the fact that even though they were in training for track, they were not necessarily high in aerobic power. Another factor is that walking tests usually elicit lower max VO_2 values than running tests (10)

Table 2 shows the correlation coefficients between the running events and some of the key physiological parameters. Max VO_2 in ml/kg/min was significantly correlated with the 1 mile run (-.627), but not with any other of the runs. (A negative r means that a higher max VO_2 was associated with a lower time in the run). While the lack of significant correlations with the shorter runs is understandable, since these events theoretically depend largely on factors other than max VO_2, the nonsignificant correlation with the 2 mile run is more difficult to explain. Perhaps one factor is that a person can work at close to his max VO_2 in an event that takes 4-5 minutes (e.g. the 1 mile run) (1), while he may only be able to attain about 90 per cent of his max in an event which takes more than 10 min. (e.g. the 2 mile run) (8). Thus the max VO_2 may not itself be the limiting factor. Since endurance training results in biochemical and ultrastructural changes which enhance greatly the aerobic power of the working muscle (5) the endurance athlete may be able to run at a given per cent of his max VO_2 without producing as much lactate as a person with the same max VO_2 who has not been trained for endurance work. And this physiological quality may serve to differentiate the endurance-trained athlete from others with similar levels of aerobic power.

A recent paper by Katch (6) questioned the statistical logic behind using VO_2 expressed in ml/kg in correlational studies, and suggested the use of partial correlations between max VO_2 in l/min and performance, with weight held constant. Table 2 shows that the partial correlations obtained using this procedure were remarkably similar to those obtained using the ml/kg technique.

The correlation coefficients between submaximal HR and the 1 mile and 2 mile runs (Table 2) were significant. (The lower HR's were associated with the lower run times). The fact that the better distance runners tended to maintain a lower HR at submaximal loads on the treadmill while not necessarily demonstrating a high max VO_2, is consistent with the idea that the aerobic power of their locomotive musculature is relatively high, allowing them to extract and utilize a given amount of oxygen from a reduced blood flow. Other possible explanations for their lower submaximal HR's are: (1) they have greater stroke volumes; (2) they have greater parasympathetic tone; and/or (3) they are more efficient mechanically. Of course, this study was not designed to determine which of these mechanisms were most influential. However, if the distance runners had greater submaximal stroke volumes, then presumably their maximum stroke volumes and, hence, their max VO_2's would have been higher.

If a generally greater parasympathetic tone were responsible, then we might expect that predicted max VO_2, which is derived from submaximal HR in a task which uses somewhat different muscles, would be related to distance running performance. However, table 2 shows that predicted max VO_2 was not significantly related to run times. And the fact that submaximal VO_2 was not significantly related to distance run times (table 2) implies that the good distance runners were not more efficient mechanically. Therefore, they hypothesis that the lower submaximal HR's were the result of better local aerobic power in the working muscles seems most plausible. This hypothesis is consistent with some recent data which showed that endurance training can reduce submaximal HR without increasing max VO_2 (13) and is also specific to the muscles involved (4). However, the fact that the r's between submaximal HR and run times were negative, although generally not significant, implies that the sprinters may have had somewhat greater sympathetic tone. This is consistent with the finding by Mc Ardle et al (11) that the anticipatory HR response of sprinters before starting their race was greater than that of control subjects, while the anticipatory response of distance runners was similar or slightly less than that of the controls. This pattern may have been clearer if we had used a sprint event shorter than the 220.

The fact that max VO_2 did not provide much information about distance running performance which was not already provided by submaximal HR was shown by the multiple R's which were computed using both max VO_2 and HR at the 0 per cent grade as independent variables. The multiple R (758) for the 1 mile run was slightly higher than the simple r using HR (.719), and for the 2 mile run the multiple R was identical to the simple r using submaximal HR (.671).

Table 3 shows the relationship between the predicted and measured max VO_2 values. The nonsignificant correlations imply that treadmill max VO_2 is predicted rather poorly from cycling HR. On the other hand, the correlations between submaximal HR's on the treadmill and max VO_2 varied from -.726 to -.570 with a mean of -.65, and all but one were significant, implying that the prediction of max VO_2 determined on one modality (e.g. the treadmill) is more effective if submaximal HR is determined on a similar modality.

In summary, this study showed that in a group of college trackmen, distance running performance was more reliably related to submaximal HR than to max VO_2, perhaps because the physiological factors which permit a person to work at a submaximal load are reflected more clearly in submaximal HR than in max VO_2.

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TABLE 1

Descriptive Statistics for Subjects

	Mean	Standard Deviation
Age (years)	19.6	.90
Weight (kg)	68.45	6.28
Height (cm)	179.8	8.60
Resting HR (bpm)	74.5	13.23
Maximum HR (bpm)	179.9	8.75
Max VO_2 (l/min)	3.59	.47
Max VO_2 (ml/kg/min)	52.46	4.69
220 yard dash (sec)	23.98	1.12
440	53.60	3.28
880	122.27 (2.04 min.)	3.90
1 mile	280.18 (4.67 min.)	16.75
2 mile	634.73 (10.58 min.)	37.99

TABLE 2

Correlation Coefficients Between Running Events and Selected Physiological Parameters

Physiological Parameters	Running Events 220 yds.	440 yds.	880 yds.	1 mile	2 mile
Max VO_2 (ml/kg/min)	.205	.080	-.288	-.627*	-.408
Max VO_2 (l/min, partial r with weight held constant)	.198	.057	-.287	-.613	-.442
Submax HR (mean and range of r's at 3.5 mph and grades of 0-17.5 degrees)	-.519 -.637 to -.395	-.305 -.506 to -.181	.183 .093 to .257	.728* .669 to .813	.675* .566 to .803
Multiple R using max VO_2 (ml/kg) and HR at 0 grade				.758*	.671
Predicted Max VO_2 (ml/kg/min)	.282	.495	.439	-.247	-.234
VO (ml/kg, mean and range of r's at submax loads on TM)	.226 -.161 to .546	.080 -.244 to .364	.145 -.136 to .270	-.090 -.332 to .234	-.244 -.611 to .040

*Note: For the simple correlations an r of .602 is needed for significance at the .05 level, whereas the multiple and partial coefficients must surpass .726 for significance.

TABLE 3

Relationship Between Predicted Max VO_2 Using the Astrand - Ryhming Bicycle Ergometer Procedure and Max VO_2 Measured on the Treadmill

	Mean		Standard Deviation	Correlation Coefficient
Max VO_2 (l/min)	3.59		.47	.58
Predicted max VO_2 (l/min)	3.35		.45	
Difference	.24	(6.68%)		
Max VO_2 (ml/kg)	52.46		4.69	.43
Predicted max VO_2 (ml/kg)	49.04		6.63	
Difference	3.42	(6.52%)		